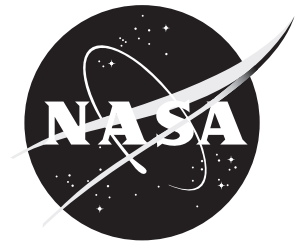


NASA Facts

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Magellan Mission to Venus

NASA's Magellan spacecraft used a sophisticated imaging radar to make the most highly detailed maps of Venus ever captured during its four years in orbit around Earth's sister planet from 1990 to 1994.

After concluding its radar mapping, Magellan made global maps of Venus's gravity field. Flight controllers also tested a new maneuvering technique called aerobraking, which uses a planet's atmosphere to slow or steer a spacecraft.

Craters shown in the radar images that Magellan sent to Earth tell scientists that Venus's surface appears relatively young -- resurfaced about 500 million years ago by widespread volcanic eruptions. The planet's present harsh environment has persisted at least since then, with no features detected suggesting the presence of oceans or lakes at any time in the planet's past.

Scientists also found no evidence of plate tectonics, the movements of huge crustal masses on Earth that cause earthquakes and result in the drifting of

continents over time spans of hundreds of millions of years.

Magellan's mission ended with a dramatic plunge to the planet's surface, the first time an operating planetary spacecraft has ever been intentionally crashed. Contact was lost with the spacecraft October

12, 1994, at 10:02 Universal Time (3:02 a.m. Pacific Daylight Time). The purpose of the maneuver was for Magellan to gather data on Venus's atmosphere before it ceased to function during its fiery descent.

Mission Overview

Magellan was the first planetary spacecraft to be launched by a space shuttle when it was carried aloft by the shuttle Atlantis from Kennedy Space Center in Florida on May 4, 1989.

Atlantis took Magellan into low Earth orbit, where it was released from the shuttle's cargo bay. A solid-fuel motor called the Inertial Upper Stage (IUS) then fired, sending Magellan on a 15-month cruise looping around the Sun 1-1/2 times before it arrived at Venus



on August 10, 1990. A solid-fuel motor on Magellan then fired, placing the spacecraft in orbit around Venus.

Magellan's initial orbit was highly elliptical, taking it as close as 294 kilometers (182 miles) from Venus and as far away as 8,543 kilometers (5,296 miles). The orbit was a polar one, meaning that the spacecraft moved from south to north or vice versa during each looping pass, flying over Venus's north and south poles. Magellan completed one orbit every 3 hours, 15 minutes.

During the part of its orbit closest to Venus, Magellan's radar mapper imaged a swath of the planet's surface approximately 17 to 28 kilometers (10 to 17 miles) wide. At the end of each orbit, the spacecraft radioed back to Earth a map of a long ribbon-like strip of the planet's surface captured on that orbit. Venus itself rotates once every 243 Earth days. As the planet rotated under the spacecraft, Magellan collected strip after strip of radar image data, eventually covering the entire globe at the end of the 243-day orbital cycle.

By the end of its first such eight-month orbital cycle between September 1990 and May 1991, Magellan had sent to Earth detailed images of 84 percent of Venus's surface. The spacecraft then conducted radar mapping on two more eight-month cycles from May 1991 to September 1992. This allowed it to capture detailed maps of 98 percent of the planet's surface. The follow-on cycles also allowed scientists to look for any changes in the surface from one year to the next. In addition, because the "look angle" of the radar was slightly different from one cycle to the next, scientists could construct three-dimensional views of Venus's surface.

During Magellan's fourth eight-month orbital cycle at Venus from September 1992 to May 1993, the spacecraft collected data on the planet's gravity field. During this cycle, Magellan did not use its radar mapper but instead transmitted a constant radio signal to Earth. If it passed over an area of Venus with higher than normal gravity, the spacecraft would slightly speed up in its orbit. This would cause the frequency of Magellan's radio signal to change very slightly due to the Doppler effect -- much like the pitch of a siren changes as an ambulance passes. Thanks to the ability of radio receivers in the

NASA/JPL Deep Space Network to measure frequencies extremely accurately, scientists could build up a detailed gravity map of Venus.

At the end of Magellan's fourth orbital cycle in May 1993, flight controllers lowered the spacecraft's orbit using a then-untried technique called aerobraking. This maneuver sent Magellan dipping into Venus's atmosphere once every orbit; the atmospheric drag on the spacecraft slowed down Magellan and lowered its orbit. After the aerobraking was completed between May 25 and August 3, 1993, Magellan's orbit then took it as close as 180 kilometers (112 miles) from Venus and as far away as 541 kilometers (336 miles). Magellan also circled Venus more quickly, completing an orbit once every 94 minutes. This new, more circularized orbit allowed Magellan to collect better gravity data in the higher northern and southern latitudes near Venus's poles.

After the end of that fifth orbital cycle in April 1994, Magellan began a sixth and final orbital cycle, collecting more gravity data and conducting radar and radio science experiments. By the end of the mission, Magellan captured high-resolution gravity data for about 95 percent of the planet's surface.

In September 1994, Magellan's orbit was lowered once more in another test called a "windmill experiment." In this test, the spacecraft's solar panels were turned to a configuration resembling the blades of a windmill, and Magellan's orbit was lowered into the thin outer reaches of Venus's dense atmosphere. Flight controllers then measured the amount of torque control required to maintain Magellan's orientation and keep it from spinning. This experiment gave scientists data on the behavior of molecules in Venus's upper atmosphere, and lent engineers new information useful in designing spacecraft.

On October 11, 1994, Magellan's orbit was lowered a final time, causing the spacecraft to become caught in the atmosphere and plunge to the surface; contact was lost the following day. Although much of Magellan was believed to be vaporized, some sections probably hit the planet's surface intact.

Venus

One of the handful of planets known to the ancients, Venus is often called Earth's sister planet because of its similar size and distance from the sun. Earth is 12,756 kilometers (7,926 miles) in diameter,

compared to Venus at 12,103 kilometers (7,520 miles); Earth orbits the sun at an average 149.6 million kilometers (93 million miles), compared to Venus at 108.2 kilometers (67.2 million miles). The two planets' densities are also similar -- 5.52 grams per cubic centimeter for Earth, compared to 5.24 grams per cc for Venus. Because Venus is closer to the sun than Earth is, it always appears close to the sun from our point of view as either a glistening, bright evening or morning "star."

Despite the similarities, however, in other ways Venus is very much unlike Earth. Venus has a surface temperature of about 470 degrees Celsius (about 900 degrees Fahrenheit); the atmospheric pressure at the surface is 90 times greater than Earth's. Venus's atmosphere is nearly devoid of water, made up of 97 percent carbon dioxide; its upper clouds contain sulfuric acid. Venus has no moons, and no magnetic field has been detected. It rotates on its axis in a retrograde direction -- that is, opposite that of Earth and most of the other planets -- very slowly, once every 243 Earth days.

The first spacecraft mission to another planet was the NASA/JPL spacecraft Mariner 2, which executed a flyby of Venus in December 1962. Other U.S. spacecraft to visit Venus have included Mariner 10, which flew by Venus in 1974 on its way to Mercury in the first mission to more than a single planet; and Pioneer Venus, a 1978 mission that included an orbiter with an altimeter and imaging radar that functioned at lower resolution than Magellan's, as well as multiple probes that descended into Venus's atmosphere. The then-Soviet Union also sent a number of spacecraft to Venus, including four -- Venera 9, 10, 13 and 14 -- that landed on the surface and made closeup pictures of the rocky terrain briefly before the searing heat caused them to stop functioning. Two other Soviet missions, Venera 15 and 16, used orbiting imaging radar similar to Magellan's but at a lower resolution.

The Magellan Spacecraft

Built partially with spare parts from other missions, the Magellan spacecraft was 4.6 meters (15.4 feet) long, topped with a 3.7-meter (12-foot) high-gain antenna. Mated to its retrorocket and fully tanked with propellants, the spacecraft weighed a total of 3,460 kilograms (7,612 pounds) at launch.

The high-gain antenna, used for both communication and radar imaging, was a spare from the NASA/JPL Voyager mission to the outer planets, as were Magellan's 10-sided main structure and a set of thrusters. The command data computer system, attitude control computer and power distribution units are spares from the Galileo mission to Jupiter. Magellan's medium-gain antenna is from the NASA/JPL Mariner 9 project. Martin Marietta Corp. was the prime contractor for the Magellan spacecraft, while Hughes Aircraft Co. was the prime contractor for the radar system.

Magellan was powered by two square solar panels, each measuring 2.5 meters (8.2 feet) on a side; together they supplied 1,200 watts of power. Over the course of the mission the solar panels gradually degraded, as expected; by the end of the mission in the fall of 1994 it was necessary to manage power usage carefully to keep the spacecraft operating.

The mission was named for the 16th-century Portuguese explorer whose mission first circumnavigated the Earth by ocean.

Imaging Radar

Because Venus is shrouded by a dense, opaque atmosphere, conventional optical cameras cannot be used to image its surface. Instead, Magellan's imaging radar uses bursts of microwave energy somewhat like a camera flash to illuminate the planet's surface.

Magellan's high-gain antenna sends out millions of pulses each second toward the planet; the antenna then collects the echoes returned to the spacecraft when the radar pulses bounce off Venus's surface. The radar pulses are not sent directly downward but rather at a slight angle to the side of the spacecraft, the radar is thus sometimes called "side-looking radar." In addition, special processing techniques are used on the radar data to result in higher resolution as if the radar had a larger antenna, or "aperture"; the technique is thus often called "synthetic aperture radar," or SAR.

Synthetic aperture radar was first used by NASA on JPL's Seasat oceanographic satellite in 1978; it was later developed more extensively on the Spaceborne Imaging Radar (SIR) missions on the space shuttle in 1981, 1984 and 1994. An imaging radar is also planned as part of the NASA/JPL Cassini mission to Saturn in 1997 to map the surface of the

ringed planet's major moon Titan.

Besides its use in imaging, Magellan's radar system was also used to collect altimetry data showing the elevations of various surface features. In this mode, pulses were sent directly downward and Magellan measured the time it took a radar pulse to reach Venus and return in order to determine the distance between the spacecraft and the planet.

Science Results

Magellan returned maps of Venus's surface and its gravity field in unprecedented detail that will be a resource for many years for scientists studying the planet. The mission held many surprises for scientists, and resulted in a number of theories about the planet being revised.

From the craters visible in Magellan's Venus maps, scientists believe they are looking at a relatively young planetary surface, perhaps about 500 million years old. Since Venus formed at the same time as Earth 4.6 billion years ago, some event or events 500 million years ago must have resurfaced the planet. Scientists believe that this may have been the work of massive outpourings of lava from planet-wide volcanic eruptions. Although Venus may still have active volcanoes, no visible outpourings of lava have yet been detected in comparisons of Magellan images between one eight-month orbital cycle and another.

Although some scientists speculate that Venus may have once been a temperate planet that fell victim to a runaway greenhouse effect creating enormously high temperatures, Magellan's maps show no telltale signs of past major water bodies such as shorelines or ocean basins. Also, surface features show no evidence of being eroded by water -- although there is evidence of wind erosion in the form of numerous sand dunes and wind streaks.

One of the hopes that scientists had for Magellan was to find out if Venus, like Earth, has plate tectonics -- movements of crustal masses that on Earth

cause earthquakes and result in the drifting of continents over time periods of hundreds of millions of years. They in fact found no evidence of plate tectonics in the data returned by the mission. Scientists suspect that, although Venus is very similar in size to Earth, its interior is probably different in major ways. In particular, Venus seems to lack an "asthenosphere," a buffer layer within Earth between the outer part of the planet and the mantle beneath. As a result, the gravity signature of features on Venus closely reflect surface topography, whereas on Earth such a correspondence does not always occur.

Scientists are also intrigued by the distribution of volcanoes around Venus. On Earth, volcanoes occur in groups such as the so-called "Ring of Fire" around the Pacific Rim. Venus, by contrast, is peppered with hundreds of thousands to millions of volcanoes distributed more or less randomly around the planet. Scientists were also surprised to see huge channels thousands of kilometers long on Venus. These appear to be lava channels, and frequently show a fan of lava at their mouths.

Project Management

Martin Marietta Corp. was the prime contractor for the Magellan spacecraft. Hughes Aircraft Co. was the prime contractor for the radar system.

At NASA Headquarters, the post of program manager was held successively by Rodney Mills, Dr. William L. Piotrowski and Elizabeth E. Beyer. Dr. Joseph M. Boyce was Magellan program scientist.

At the Jet Propulsion Laboratory, the post of project manager was held successively by John Gerpheide, Anthony Spear, James Scott and Douglas Griffith. Dr. R. Stephen Saunders was Magellan project scientist. JPL managed the Magellan project for NASA's Office of Space Science.

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